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ORIGIN OF THE LYMAN SCHISTS OF NEW HAMPSHIRE

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INTRODUCTION

During the summers of 1911 and 1912, through the generosity of Mr. R. W. Sayles, I made a geological investigation of part of the townships of Littleton, Lisbon, Lyman, Bethlehem, Bath, and Landaff, in New Hampshire. In the fifteen weeks devoted to this work about 250 square miles were examined. The results that have been published[1] have reference to an area of only eight or nine square miles (Fig. 1), in the study of which three of the fifteen weeks were consumed. The survey of the rest of the area amounted to a reconnaissance of intricately metamorphosed schists, regarding which final conclusions were deferred until more could be learned. Having had opportunity to revisit some parts of the field where the "Lyman schists" are exposed and having examined a suite of thin sections of these schists, I submit the present paper as a second chapter on the geology of the "Ammonoosuc District."

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[1] F. H. Lahee, "Geology of the New Fossiliferous Horizon and the Underlying Rocks, in Littleton, New Hampshire," *Am. Jour. Sci.* (4), XXXVI (1913), 231–50.

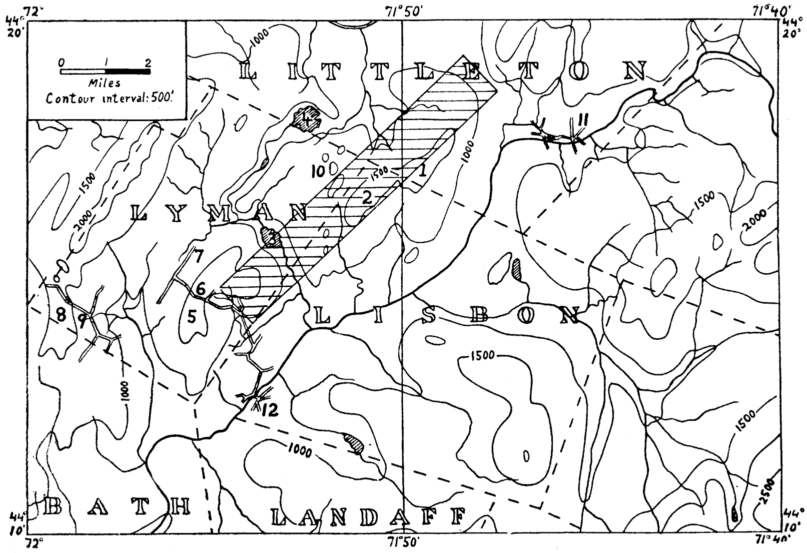

FIG. 1.—Index map of the localities mentioned in the text. The shaded rectangular area is the strip of country described in the article on the Littleton fossiliferous horizon. 1, Blueberry Mountain. 2, Bald Hill. 3, Young's Pond. 4, Partridge Lake. 5, Parker Hill. 6, the "Parker Hill locality." 7, Lyman village. 8, Black Mountain. 9, the "Black Mountain locality." 10, Mormon Hill. 11, Littleton. 12, Lisbon. Only a few roads are drawn.

I am happy to express my gratitude to Mr. W. L. Whitehead, a candidate for the doctorate of science in geology at the Institute, for making the accompanying microphotographs, and to Mr. Sayles for the use of Figs. 2 and 15.

SUMMARY

1. The term "Lyman schists" was applied by Hitchcock to a group of schists many of which are characteristically whitish on their weathered surfaces.

2. These Lyman schists are broadly exposed in the area northwest of the Blueberry Mountain–Bald Hill range and its southwestward extension.

3. Hitherto the Lyman series has been regarded as a group of metamorphosed sedimentary rocks.

4. Field evidence, megascopic examination of hand specimens, and microscopic examination of thin sections indicate that the Lyman series contains interbedded members which appear to be of volcanic origin.

5. These metamorphosed volcanic rocks include, among others, species related to the quartz keratophyres and the keratophyres, and probably also tuffs and agglomerates of similar composition.

6. It seems more reasonable to attribute the origin of the coarse conglomerate schist near Young's Pond, Lyman, to vulcanism than to glaciation.

7. The association of acidic effusives with the Paleozoic rocks east of the main Appalachian protaxis is not exceptional for New Hampshire. Such effusives are found in Maine, in the Maritime Provinces of Canada, and in the Piedmont Plateau of our middle and southern Atlantic border states.

THE LISBON AND LYMAN SERIES

On the northwestern side of the Blueberry Mountain formation[1] are highly metamorphosed greenish and whitish schists which outcrop over many square miles. The greenish varieties are often chloritic. They and certain other associated rocks were called by Hitchcock the "Lisbon group." The whitish schists belong to his "Lyman group." In his earlier reports he relegated these two formations to the Huronian,[2] the Lyman group being considered the younger member; but subsequently he referred them to the Cambrian or to the Ordovician,[3] and concluded that "the Lyman schists . . . . do not represent a stratigraphical terrane"; the term "is a petrographical designation."[4]

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[1] F. H. Lahee, *op. cit.*

[2] C. H. Hitchcock, *Geology of New Hampshire* (1877), II, 277.

[3] *Ibid.; Geology of Littleton, New Hampshire,* reprint from the *History of Littleton* (1905), pp. 11, 29.

[4] *Ibid.*, p. 31.

GENERAL DISTRIBUTION OF THE LYMAN SERIES

No attempt will be made here to mark out the exact distribution of this series. It is exposed over broad areas west of the Blueberry Mountain Siluro-Devonian belt and it may be related to schists on the east of this belt. The principal localities (Fig. 1) to which reference will be made in the sequel are Mormon Hill, the valley just northwest of Young's Pond, and Parker Hill. Lyman schists are also exposed on the hill southwest of Young's Pond, on the lower eastern slope of Black Mountain, near Partridge Lake, and elsewhere in the broad valley between Gardner Mountain and the Mormon Hill–Parker Hill range. In all these places the group has a breadth of outcrop of several hundred feet, the rocks are schistose, the strikes are roughly northeast-southwest, and the cleavage and the bedding (where visible) have steep dips.

FIELD RELATIONS AND MEGASCOPIC DESCRIPTIONS OF THE LYMAN SERIES

The Young's Pond locality.—Near a small schoolhouse about one-third of a mile northwest of Young's Pond is a large outcrop of a conglomeratic schist which we used to speak of as the "schoolhouse conglomerate" (Fig. 2). It is the rock which Mr. Sayles has recently described as possibly being a tillite.[1] This conglomerate schist appears to rest unconformably upon a whitish or light-grayish porphyritic sericite schist. The contact, which is very irregular, runs northeast-southwest and may be seen not only near the schoolhouse, but also, a few hundred feet southwest, near the brook that flows into Young's Pond. The conglomerate schist is on the northwest, the porphyry schist on the southeast, of this contact. The conglomerate schist is between 300 and 400 feet wide across the strike, and the porphyry schist is between 150 and 250 feet wide. This statement should not be understood to imply that these rocks have no variation across their outcrop belts. There is evidence that the porphyry is interrupted at least at one horizon by a bed of fine conglomerate schist.

West of the "schoolhouse conglomerate" is a series of whitish rocks including fine, non-porphyritic schists, fine porphyritic schists, fine conglomerate schists in which the pebbles and paste are of similar whitish materials and the pebbles are much sheared, and schists of the texture of medium sandstones. The last-mentioned material and some of the finer conglomerate schists looked so much like altered pyroclastics that they were called tuffs in the field. (See description of the Parker Hill white schist, below.) All these rocks are exposed more than once across the strike.

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[1] R. W. Sayles, "Tillite in New Hampshire," *Science*, N.S., XLI (1915), 220.

The porphyry schist that underlies the "schoolhouse conglomerate" has an exceedingly fine groundmass, which is sericitic and in places rich in chlorite. The phenocrysts, ranging up to nearly $\frac{1}{2}$ inch in diameter, but averaging $\frac{1}{8}$–$\frac{3}{16}$ inch, are of quartz and plagioclase. They are uniformly distributed and constitute about half of the rock. The quartz has a very high luster, is somewhat bluish and very transparent, and has tendency to break with a rude cleavage. The plagioclase is so fresh that the striations are distinct and the fracture surfaces are brightly reflecting. The shearing of the rock seems to have been localized in the groundmass. Within its own mass this schist has no bedding.

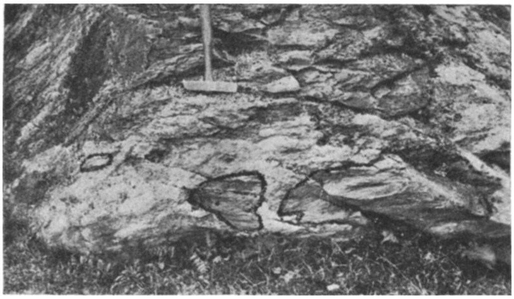

FIG. 2.—Lyman ("schoolhouse") conglomerate, showing obscure outlines of pebbles. The dark masses, edged with black enamel, are of the fine drab schist. Photograph by Mr. Sayles.

The conglomerate schist ("schoolhouse conglomerate"), also, is quite devoid of bedding. It contains many large and small fragments of the porphyry schist, together with pieces of other whitish rocks of the Lyman series, and masses of rust-brown, smooth-looking schist, which are conspicuously darker than the Lyman varieties. All the pebbles have been more or less sheared and in such a way that their longest axes are parallel with the dip of the cleavage. Some seem to have been roundish, but more often they were obviously angular. Naturally the shearing has increased the irregularity of their shapes.

The quartz-plagioclase porphyry pebbles have been deformed less than the other varieties. Their average dimensions may be expressed by the ratio 2:1.25:1. They range up to two feet in length.

The dark fragments, mentioned above, are often drab-colored on the weathered surface, but dark-greenish when fresh. As will be explained presently, they are chlorite and actinolite schists. They are of medium fine grain and of uniform texture, they are markedly sheared, and their shape is very irregular, even jagged. Some were found to be 10 or 12 feet long and only 1 or 2 feet wide. Others are less elongate (Fig. 2).

As compared with the pebbles, the paste of this conglomerate schist is in relatively small amount. Nor does it seem to have been derived from an argillitic substance. It looks rather as if it had been fine clastic débris, of texture ranging from fine sandstone to fine conglomerate, derived from the same sources whence came the larger pebbles. Its appearance is that of metamorphosed tufaceous material. Partly on account of the metamorphism and partly because of similarity of character, the paste is not sharply defined from the pebbles. On fresh surfaces of the rock the pebbles are distinguished with difficulty, and even on weathered exposures, where the psephitic structure is best brought out, the details are blurred.

The Mormon Hill locality.—On a traverse across the strikes on Mormon Hill, one passes over a series of schists much like those near Young's Pond. They are porphyries, tuff-like clastic rocks, and fine and coarse psephites, all sheared. They dip steeply northwest. In one place obscure cross-bedding indicated that the stratigraphic sequence was younger westward; and in another locality the same fact was shown by an unconformable contact between tuff-like schist on the southeast and conglomerate schist on the northwest. The series was roughly measured as having a breadth of outcrop of 800 feet.

The porphyry schist of this region differs from that near Young's Pond in lacking quartz phenocrysts. Its phenocrysts are all of plagioclase. Otherwise, in respect to size, abundance, and arrangement of phenocrysts and characters of the groundmass, it is megascopically like the type above described.

The coarse psephitic rocks here contain fragments of whitish and drab schists, as at Young's Pond.

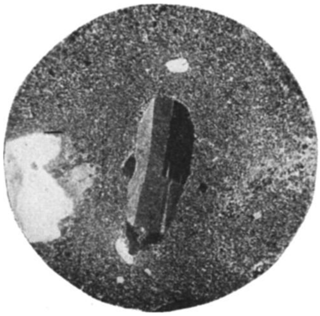

FIG. 3.—Rounded plagioclase phenocryst surrounded by groundmass. Enlarged 16 diameters. The large white areas are due to imperfections on the negative.

The Parker Hill locality.—Porphyry schists, tuff-like schists, and psephite schists are here exposed in a belt several hundred feet wide. The porphyry schists are finer than the Young's Pond type. Along the road that crosses Parker Hill between Lisbon and Lyman villages exposures near the top of the hill exhibit curious relations. A dark-gray schist (called hereafter the Parker Hill dark schist) is associated with a whitish rock of the Lyman series. The latter, which will be called the Parker Hill white schist, in several outcrops, constitutes a matrix in which are scattered large and small irregular blocks and strips of the dark schist, many being greatly contorted. The phenomenon resembles intraformational pebbles in clastic material. The white schist is of the texture of a medium sandstone. Quartz and feldspar are both abundant and the interstices between the larger grains are filled with finer particles of quartz and feldspar, together with secondary mica. The dark schist is phyllitic. Some specimens of it have minute phenocrysts in a still finer groundmass.

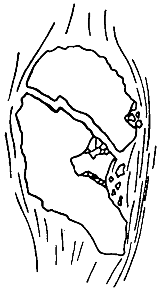

FIG. 4.—Broken quartz phenocryst. The curving lines indicate the arrangement of mica laths. Enlarged 16 diameters.

MICROSCOPIC DESCRIPTIONS

Porphyry schist of the Young's Pond locality.—Thin sections of the porphyry schist from near the schoolhouse northwest of Young's Pond show a nearly uniform groundmass. The diameters of the smaller phenocrysts are thirty or forty times those of the larger groundmass grains and there is no gradation between the two (Fig. 3).

Clear, but with a few vacuoles, the quartz phenocrysts display only slight crushing, and this is mostly peripheral (Figs. 4–7). Their corners have been rounded. Several individuals are invaded by long narrow bays of the groundmass (Figs. 5 and 8). It is worth while noting that, although the outer borders of these phenocrysts are jagged on account of granulation and penetration by mica laths, the edges of the embayments are clean-cut and smoothly curving.

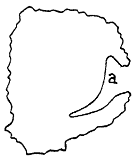

FIG. 5

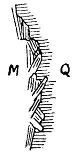

FIG. 6

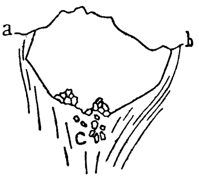

FIG. 7

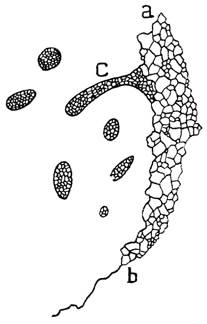

FIG. 8

FIG. 5.—Quartz phenocryst with edges serrate on account of marginal granulation and penetration by mica laths. Note smooth outline of the embayment (*a*). Enlarged 26 diameters.

FIG. 6.—Detail of outer edge of the quartz phenocryst represented in Fig. 5. The shaded area is quartz (*Q*). The small laths are mica (*M*).

FIG. 7.—Quartz phenocryst showing terminal granulation at pole of minimum compression (*c*). *a–b* is the edge of the thin section. Enlarged 20 diameters.

FIG. 8.—Part of a large quartz phenocryst. The border zone, *a–b*, is a granulated portion of the phenocryst. Outside this zone is the much finer, uniform groundmass (not figured). Several embayments of the groundmass are shown, one cut longitudinally (*c*), and the others intersected transversely at various angles. Note regular outlines of these embayments as compared with the jagged border of the grain as a whole. The figure is drawn from a microphotograph, but not with absolute precision in the finer details. Enlarged 16 diameters.

Like the quartz, the plagioclase phenocrysts are not severely crushed (Fig. 9). The angle of extinction on sections approximately perpendicular to the albite twinning varied between 13° and 17°. This and the fact that the index of refraction was always lower than that of balsam indicate that the mineral is albite. Some grains have very good crystal outlines (Fig. 10), but as a rule they have had their corners more or less rounded (Fig. 3).

As for the groundmass, it consists of abundant quartz and chlorite, with some sericite and feldspar. It is so fine that microscopic discrimination between quartz and feldspar is almost impossible. Both chlorite and sericite show some tendency to parallel arrangement. The chlorite is likely to occur in larger flakes in the lee of the phenocrysts and in the quartz embayments—in other words, where there was some protection from the shearing stress, such as it was. Neither quartz nor feldspar phenocrysts contain scattered inclusions of the groundmass.

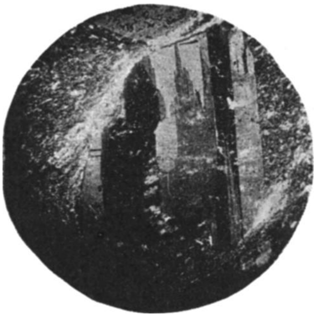

FIG. 9.—A plagioclase phenocryst showing the bundles of sericite laths that wrap round it at the poles of maximum compression. Enlarged 11 diameters.

The porphyry from the channel of the brook running into Young's Pond is somewhat more sheared than that from the schoolhouse ledge. The quartz and feldspar phenocrysts are more strained and granulated, and in some places the broken fragments are separated by a strip having cataclastic structure (Fig. 11). Sericite is more abundant and has better orientation. It is often thickly plastered against the phenocrysts about which it wraps at the poles of maximum compression (Fig. 9). In other respects this schist is similar to the less metamorphosed specimens.

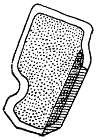

FIG. 10.—Plagioclase phenocryst with zonal structure and crystal form. The inner, stippled part of the crystal is somewhat decayed. Enlarged 32 diameters.

Pebbles of the conglomerate schist of the Young's Pond locality.—Pebbles of the porphyry schist are identical with the bedrock of the same. They need no further description here.

The dark masses which have been mentioned as greenish when fresh, but drab when weathered, are of peculiar interest, since they have been regarded as highly metamorphosed blocks of argillite. They have been compared with the slate blocks in the Squantum tillite.[1] Thin sections were prepared from several fragments taken from different outcrops of the "schoolhouse conglomerate." Microscopic examination revealed two distinct varieties. One is composed largely of zoisite and bundles of parallel actinolite needles, with some chlorite and titanite and a little plagioclase. The other is rich in chlorite, plagioclase, and zoisite, and contains titanite and a little epidote and sericite. This schist is finely porphyritic, the phenocrysts being of plagioclase (Fig. 12). Many have been bent, sliced, or granulated by the shearing. The white mica is fairly well oriented and, together with the other minerals, is inclosed in an irregular background or network of chlorite. There are some chlorite aggregates which look as if they had formed from a mineral that was once present as phenocrysts. No quartz is recognizable in either rock.

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[1] R. W. Sayles, *op. cit.*

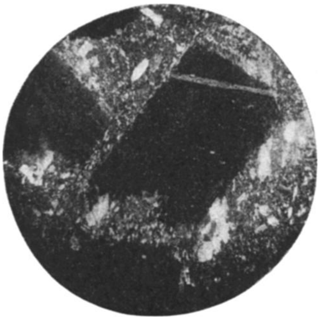

FIG. 11.—"Torn" plagioclase phenocryst. The large dark area in the middle of the photograph is about one-third of the entire crystal, the other two-thirds being below the picture. The irregular lower edge is the "torn" end. Enlarged 20 diameters.

With reference to the origin of these rocks, it would seem as if their source was most probably igneous. Some of them might have been derived from sedimentary products of incomplete decomposition, but they can hardly have come from normal argillitic material.

Parker Hill white schist.—The whitish schist that contains the dark phyllitic fragments is composed principally of quartz and orthoclase in nearly equal proportions, somewhat less plagioclase, and some chlorite and sericite. The particles of quartz and feldspar have every gradation in size from the largest to the smallest (Fig. 13). There is relatively little matrix, the larger grains being so numerous that they nearly,

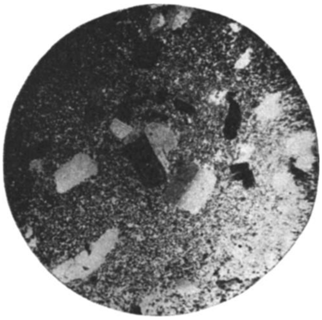

FIG. 12.—Section of a pebble of fine porphyry schist from the "schoolhouse conglomerate" at the Black Mountain locality. Enlarged 16 diameters.

if they do not quite, touch one another. Many of the grains are angular; none is conspicuously rounded, and they do not seem to have been rounded before metamorphism. Of the two minerals, sericite and chlorite, the latter is most plentiful. The chlorite is least likely to have parallel orientation. Another specimen from farther northeast near this horizon exhibited similar characters in thin section.

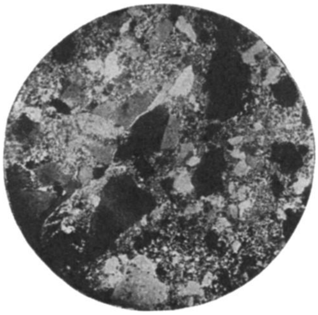

FIG. 13.—Section of a typical psammitic member of the Lyman series. Enlarged 12 diameters.

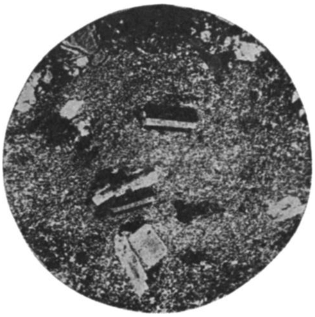

FIG. 14.—Section of a porphyritic pebble of the "Parker Hill dark schist." Enlarged 15 diameters.

Parker Hill dark schist.—The specimen from which the section was cut was obtained northeast of Parker Hill along the strike of the rock exposed in the Lisbon-Lyman road, and it is thought to belong to the same horizon. The phyllite is a small angular fragment in a whitish clastic matrix of the kind just described. It is porphyritic (Fig. 14), having small phenocrysts (0.13–1.0 mm.) of plagioclase, often with well-preserved crystal form, distributed in a very fine groundmass of plagioclase and chlorite. The phenocrysts do not

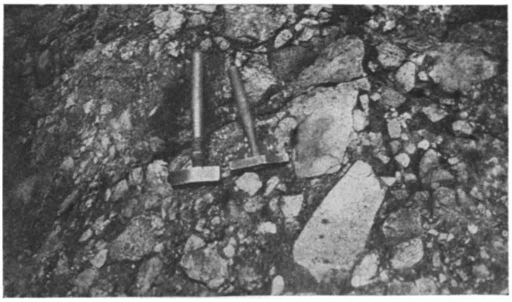

FIG. 15.—Part of the "egg conglomerate" where the majority of the pebbles are angular and subangular. Photograph by R. W. Sayles.

contain inclusions of the groundmass. This rock is remarkably like a pebble taken from a conglomerate which Hitchcock[1] called the "egg conglomerate" (see Fig. 15), a pebble which would be called a felsitic rock without hesitation.

GENERAL CONCLUSIONS ON THE ORIGIN OF THE LYMAN SCHISTS

Among the characters described in the foregoing paragraphs many are of such a nature as to suggest that at least some members of the Lyman schist group are igneous rocks—probably volcanic—more or less modified by dynamic metamorphism. For the sake of clearness and emphasis, the significant facts which lead to this conclusion are reviewed below in summary form for three typical rocks.

Porphyry schist of the Young's Pond locality.—The quartz-plagioclase porphyry schist which has been described from the Young's Pond locality is assumed to have been an effusive rock for the following reasons:

1. It has a strong resemblance to the quartz porphyry type of igneous rock.
2. It is massive, without bedding.
3. Locally it has faint indications of flow structure.
4. The phenocrysts are rather uniformly distributed through the groundmass.
5. The quartz phenocrysts have high luster and high transparency, a faint bluish opalescence, and a tendency toward cleavage, all these being features not uncommon in true quartz porphyries.
6. Some of the feldspar phenocrysts have crystal form.
7. There is a great difference between the size of the smaller phenocrysts and that of the larger groundmass particles.
8. Many quartz phenocrysts and some feldspar phenocrysts contain embayments of the groundmass, these embayments having

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[1] C. H. Hitchcock, *Geology of New Hampshire* (1877), II, 333. This "egg conglomerate" is exposed on the northwest slope of Blueberry Mountain and may grade laterally into the Fitch Hill arkose. Most of its pebbles are of quartz porphyry, quartz keratophyre, granophyre, devitrified rhyolite, and other felsitic types. The great preponderance of effusive rocks among the pebbles is to be noted for comparison with the Lyman series.

regular curving edges evidently due to magmatic corrosion and not to subsequent localized granulation or recrystallization.

9. Some feldspar phenocrysts have zonal structure parallel to the outlines of the corrosion inserts of the groundmass (Fig. 10).

10. Both quartz and feldspar phenocrysts, and even those feldspar crystals which have zonal structure, are quite free from the type of inclusion of the groundmass which is so common in many metacrysts.

11. Although two or three feldspar crystals are sometimes attached as if they had grown so (Fig. 16), quartz and feldspar never occur thus together. If the materials of the schist were derived from the breaking up of a granitoid rock, small pebbles composed of both quartz and feldspar would be expected.

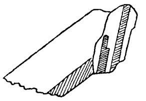

FIG. 16.—Two attached plagioclase individuals which occur as a phenocryst. Enlarged 7 diameters.

12. All, or nearly all, of the feldspar phenocrysts are albite. A clastic rock would be likely to contain several species of fragmental feldspar, for there are plenty of rocks in this region which have orthoclase, microcline, microperthite, micropegmatite, etc., among their constituents.

13. The abundance of albite in this rock suggests that the content of Na may be abnormally high for an argillitic sediment. However, I have not analyzed the rock chemically, and the Rosiwal method would be unsatisfactory on account of the difficulty of determining the particles of the groundmass.

14. The preponderance of easily recognized pebbles of felsitic rocks in the "egg conglomerate" proves that acidic effusive rocks may be expected in the region.

If, then, we grant that the quartz-plagioclase porphyry schist is effusive, its composition places it in the class of quartz keratophyres, and the similar quartzless rock of Mormon Hill belongs to the keratophyres.

Parker Hill white schist.—This is taken as representative of the "tuff-like schists" of the Lyman group. It is undoubtedly a metamorphosed clastic as is demonstrated by the following facts:

1. Megascopically and microscopically it has a distinctly fragmental aspect.

2. Locally it contains angular blocks and sometimes isolated pebbles.

3. It grades into the fine variety of Lyman conglomerate schist.

4. It has obscure bedding (layers differing in texture) in some places.

5. There are all gradations in size between its largest and smallest particles.

6. There is a relatively small proportion of small grains as compared with the porphyry schist.

This Parker Hill white schist certainly was never a normal clastic in the ordinary sense of the term. It might be called an arkose schist on account of its having abundant clastic feldspar. However, its more or less intimate association with effusive rocks, the presence in it of the constitutents of the porphyry schists, both as small particles (quartz and albite grains, etc.) and as larger fragments (some whitish like the Lyman schists and some dark like the Parker Hill dark schist), and the observed gradations between it and the fine Lyman conglomerate schist which is composed chiefly of sheared pebbles of felsitic nature—these facts induce me to classify the rock as a metamorphosed tuff.

Conglomerate schist of the Young's Pond locality.—There is no doubt that this "schoolhouse conglomerate" looks very much like a glacial deposit, as stated by Hitchcock[1] and recently by Sayles; but if the accepted criteria for till ever did exist here, they have been entirely destroyed by metamorphism. For this reason it is futile to look for signs of glacial abrasion on an underlying rock pavement. The weakness of the evidence for glacial origin was fully appreciated by Mr. Sayles, and I may add that evidence against such glacial origin is almost, if not quite, as inconclusive. However, one should bear in mind that great variation in size of constituent fragments and absence of bedding are characters shared by talus, landslide débris, pyroclastic materials, and not infrequently even by river-laid alluvial cone deposits. Is it not more probable that the "schoolhouse conglomerate," being closely associated with an effusive rock (quartz-plagioclase porphyry schist), having a large proportion of its pebbles and bowlders consisting of effusive rocks, and having a paste which resembles the Parker Hill white schist (cf. above), is a coarse pyroclastic, an agglomerate, rather than a tillite?

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[1] C. H. Hitchcock, "New Studies in the Ammonoosuc District of New Hampshire," *Bull. Geol. Soc. Am.*, XV (1904), 472, and *Geology of New Hampshire* (1877), II, 302.

It is important to note that both Hitchcock and Hawes[1] maintained that rocks of the Lyman group were the outcome of the metamorphism of sediments. Neither of these geologists held the view that these schists were of volcanic origin, yet both were struck by the resemblance between some members of the series and ordinary felsite.

STRUCTURAL RELATIONS OF THE LYMAN SERIES

The structural relations, and therefore the age, of the Lyman schists still remain obscure. These rocks are surely not younger than Devonian, and they may be older, as has been stated by Hitchcock. In several places on the Parker Hill–Mormon Hill range stratigraphic structures point to an anticlinal axis eastward. If this is so, since the Blueberry Mountain–Bald Hill range is regarded as synclinal, the intervening valley is anticlinal. Again, if this is so, it becomes necessary to explain the lack of correlation between the Lyman schists on the western range and the marine argillites and sandstones of the eastern range. Unconformity or extensive faulting may be the cause. At present I do not feel justified in discussing this subject further. More time should be given to field investigation. The region offers ample opportunity for research in petrology and in structural geology.

ACIDIC EFFUSIVE ROCKS EAST OF THE APPALACHIAN PROTAXIS

South of the latitude of New York City the Appalachian Mountains are flanked on the east by the Piedmont Plateau. North of the same latitude, the New England Province corresponds to the Plateau. Both regions are underlain by plutonic rocks and folded, sheared, sedimentary rocks, chiefly of Paleozoic and pre-Cambrian age. With extended study of these complex rocks two results stand out conspicuously: an increasing number of metamorphosed rocks is being transferred from the pre-Cambrain to the Paleozoic, and the origin of the schists is found to be more diverse than was at first conceded. It is in line with these results that the variety and distribution of effusive rocks, both flows and pyroclastics, interbedded with the schistose Paleozoic sediments, are being expanded as investigation proceeds. In a paper written in 1894, G. H. Williams called attention to this fact.[1] He briefly described the following localities in eastern North America, where volcanic rocks were known at that time: Newfoundland, Nova Scotia, New Brunswick, that part of the province of Quebec lying west of Maine and north of Vermont and New Hampshire, Maine, Massachusetts, Pennsylvania, Maryland, Virginia, and the Carolinas. To this list it is probable that Rhode Island and New Hampshire may now be added. Williams mentioned New Hampshire in his text, but did not show any volcanic rocks in this state on his map. He observed that "in New Hampshire felsites and quartz-porphyries abound. They were regarded as eruptive by Hitchcock and by Hawes when they occur in dykes, although the latter regarded many of them, especially when interstratified, as sediments fused *in situ*."[2] This paper by Williams contains numerous references. A list of more recent articles on the subject is given by J. E. Pogue, Jr., in his "Geology and Structure of the Ancient Volcanic Rocks of Davidson County, North Carolina."[3]

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[1] C. H. Hitchcock, *Bull. Geol. Soc. Am.*, XV (1904), 468, 469; and G. W. Hawes, "Mineralogy and Lithology of New Hampshire," p. 176, in Hitchcock's *Geology of New Hampshire*, III (1878).

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[1] "Distribution of Ancient Volcanic Rocks along the Eastern Border of North America," *Jour. Geol.*, II (1894), 1–31.

[2] *Op. cit.*, p. 24.

[3] *Am. Jour. Sci.* (4), XXVIII (1909), 218–38.